

WHAT IS CLAIMED IS:

1                   1.       A method of growing an AlGa<sub>N</sub> single crystal boule, the method.  
2 comprising the steps of:  
3                   growing an AlGa<sub>N</sub> single crystal layer on a substrate;  
4                   removing said substrate from said AlGa<sub>N</sub> single crystal layer;  
5                   growing the AlGa<sub>N</sub> single crystal boule on a surface of said AlGa<sub>N</sub> single  
6 crystal layer; and  
7                   continuing said step of growing the AlGa<sub>N</sub> single crystal boule until the  
8 AlGa<sub>N</sub> single crystal boule has a length of greater than 1 centimeter.

1                   2.       The method of claim 1, wherein said step of growing said AlGa<sub>N</sub>  
2 single crystal layer on said substrate further comprises the steps of:  
3                   locating an extended Ga source within a first source zone of a reactor;  
4                   locating said substrate within a growth zone of said reactor;  
5                   locating an Al source within a second source zone of said reactor;  
6                   heating said substrate to a first temperature, wherein said first temperature  
7 is greater than 1,000 °C;  
8                   heating a first portion of said extended Ga source to a second temperature,  
9 wherein said second temperature is greater than 450 °C;  
10                  maintaining a second portion of said extended Ga source at a third  
11 temperature, wherein said third temperature is greater than 30 °C, and wherein said third  
12 temperature is less than 100 °C;  
13                  heating said Al source to a fourth temperature, wherein said fourth  
14 temperature is greater than 700 °C;  
15                  introducing a halide reaction gas into said first source zone to form a first  
16 halide metal compound;  
17                  introducing said halide reaction gas into said second source zone to form a  
18 second halide metal compound;  
19                  transporting said first halide metal compound to said growth zone;  
20                  transporting said second halide metal compound to said growth zone;

21 introducing a reaction gas into said growth zone, said reaction gas  
22 containing nitrogen; and  
23 growing said AlGa<sub>N</sub> single crystal layer on said substrate, said AlGa<sub>N</sub>  
24 single crystal layer formed by said reaction gas reacting with said first halide metal  
25 compound and said second halide metal compound.

1 3. The method of claim 2, further comprising the step of selecting  
2 HCl gas as said halide reaction gas, wherein said first halide metal compound is  
3 comprised of gallium chloride, and wherein said second halide metal compound is  
4 comprised of aluminum trichloride.

1 4. The method of claim 2, further comprising the step of selecting  
2 ammonia gas as said reaction gas.

1 5. The method of claim 2, further comprising the step of selecting  
2 said second temperature as approximately 650 °C.

1 6. The method of claim 2, wherein said step of transporting said first  
2 halide metal compound to said growth zone is further comprised of the step of flowing an  
3 inert gas through said first source zone, and wherein said step of transporting said second  
4 halide metal compound to said growth zone is further comprised of the step of flowing  
5 said inert gas through said second source zone.

1 7. The method of claim 2, further comprising the steps of:  
2 locating at least one acceptor impurity metal in a third source zone of said  
3 reactor;  
4 heating said at least one acceptor impurity metal to a fifth temperature; and  
5 transporting said at least one acceptor impurity metal to said growth zone,  
6 wherein said AlGa<sub>N</sub> single crystal layer contains said at least one acceptor impurity  
7 metal.

1 8. The method of claim 2, further comprising the steps of:  
2 locating at least one donor in a third source zone of said reactor;  
3 heating said at least one donor to a fifth temperature; and  
4 transporting said at least one donor to said growth zone, wherein said  
5 AlGa<sub>N</sub> single crystal layer contains said at least one donor.

1                   9.       The method of claim 2, further comprising the steps of:  
2                   locating a second Al source within a third source zone of said reactor;  
3                   heating said second Al source to a fifth temperature, wherein said fifth  
4 temperature is greater than 700 °C;  
5                   introducing said halide reaction gas into said third source zone to form said  
6 second halide metal compound;  
7                   transporting said second halide metal compound from said third source  
8 zone to said growth zone;  
9                   discontinuing said step of transporting said second halide metal compound  
10 from said second source zone to said growth zone; and  
11                   discontinuing said step of introducing said halide reaction gas into said  
12 second source zone.

1                   10.     The method of claim 1, wherein said step of removing said at least  
2 one substrate from said AlGaIn single crystal layer further comprises the steps of:  
3                   slicing a wafer from said AlGaIn single crystal layer; and  
4                   polishing said surface of said wafer.

1                   11.     The method of claim 10, further comprising the step of etching said  
2 polished surface.

1                   12.     The method of claim 1, wherein said step of removing said  
2 substrate from said AlGaIn single crystal layer further comprises the step of etching said  
3 substrate from said AlGaIn single crystal layer to expose said surface of said AlGaIn  
4 single crystal layer.

1                   13.     The method of claim 12, wherein said etching step further  
2 comprises the step of placing said substrate with said AlGaIn single crystal layer into a  
3 crucible containing molten KOH.

1                   14.     The method of claim 13, further comprising the step of reactive ion  
2 etching said exposed surface, said reactive ion etching step proceeding after the step of  
3 removing said substrate from said crucible of molten KOH.

1                   15.     The method of claim 12, further comprising the step of polishing  
2     said exposed surface.

1                   16.     The method of claim 15, further comprising the step of reactive ion  
2     etching said polished, exposed surface.

1                   17.     The method of claim 15, further comprising the step of chemically  
2     etching said polished, exposed surface.

1                   18.     The method of claim 1, wherein said step of removing said at least  
2     one substrate from said AlGaN single crystal layer further comprises the steps of:  
3                   polishing said substrate, wherein a first portion of said substrate is  
4     removed from said AlGaN single crystal layer through said polishing step; and  
5                   reactive ion etching said substrate, wherein a second portion of said  
6     substrate is removed from said AlGaN single crystal layer through said reactive ion  
7     etching step.

1                   19.     The method of claim 18, wherein said reactive ion etching step  
2     uses an  $\text{Si}_3\text{F}/\text{Ar}$  mixture.

1                   20.     The method of claim 1, wherein said step of growing the AlGaN  
2     single crystal boule on said surface of said AlGaN single crystal layer further comprises  
3     the steps of:  
4                   locating an extended Ga source within a first source zone of a reactor;  
5                   locating said AlGaN single crystal layer within a growth zone of said  
6     reactor;  
7                   locating an Al source within a second source zone of said reactor;  
8                   heating said AlGaN single crystal layer to a first temperature, wherein said  
9     first temperature is greater than 1,000 °C;  
10                  heating a first portion of said extended Ga source to a second temperature,  
11     wherein said second temperature is greater than 450 °C;  
12                  maintaining a second portion of said extended Ga source at a third  
13     temperature, wherein said third temperature is greater than 30 °C, and wherein said third  
14     temperature is less than 100 °C;



1 23. The method of claim 20, further comprising the step of selecting  
2 ammonia gas as said reaction gas.

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1 24. The method of claim 20, further comprising the step of selecting  
2 said second temperature as approximately 650 °C.

1 25. The method of claim 20, further comprising the steps of:  
2 locating at least one acceptor impurity metal in a third source zone of said  
3 reactor;  
4 heating said at least one acceptor impurity metal to a sixth temperature;  
5 and  
6 transporting said at least one acceptor impurity metal to said growth zone,  
7 wherein said AlGaIn single crystal boule contains said at least one acceptor impurity  
8 metal.

1 26. The method of claim 20, further comprising the steps of:  
2 locating at least one donor in a third source zone of said reactor;  
3 heating said at least one donor to a sixth temperature; and  
4 transporting said at least one donor to said growth zone, wherein said  
5 AlGaIn single crystal boule contains said at least one donor.

1 27. The method of claim 20, further comprising the steps of:  
2 locating a second Al source within a third source zone of said reactor;  
3 heating said second Al source to a sixth temperature, wherein said sixth  
4 temperature is greater than 700 °C;  
5 introducing said halide reaction gas into said third source zone to form said  
6 second halide metal compound;  
7 transporting said second halide metal compound from said third source  
8 zone to said growth zone;  
9 discontinuing said step of transporting said second halide metal compound  
10 from said second source zone to said growth zone; and  
11 discontinuing said step of introducing said halide reaction gas into said  
12 second source zone.

28. A method of growing an AlGa<sub>N</sub> single crystal boule, the method comprising the steps of:

- growing an AlGa<sub>N</sub> single crystal layer on a substrate;
- removing said substrate from said AlGa<sub>N</sub> single crystal layer;
- growing the AlGa<sub>N</sub> single crystal boule on a surface of said AlGa<sub>N</sub> single crystal layer utilizing a modified HVPE process and an extended, multi-temperature zone Ga source; and
- continuing said step of growing the AlGa<sub>N</sub> single crystal boule until the AlGa<sub>N</sub> single crystal boule has a volume in excess of 4 cubic centimeters, and wherein an x, a y, and a z dimension of said AlGa<sub>N</sub> single crystal boule each exceed 1 centimeter.